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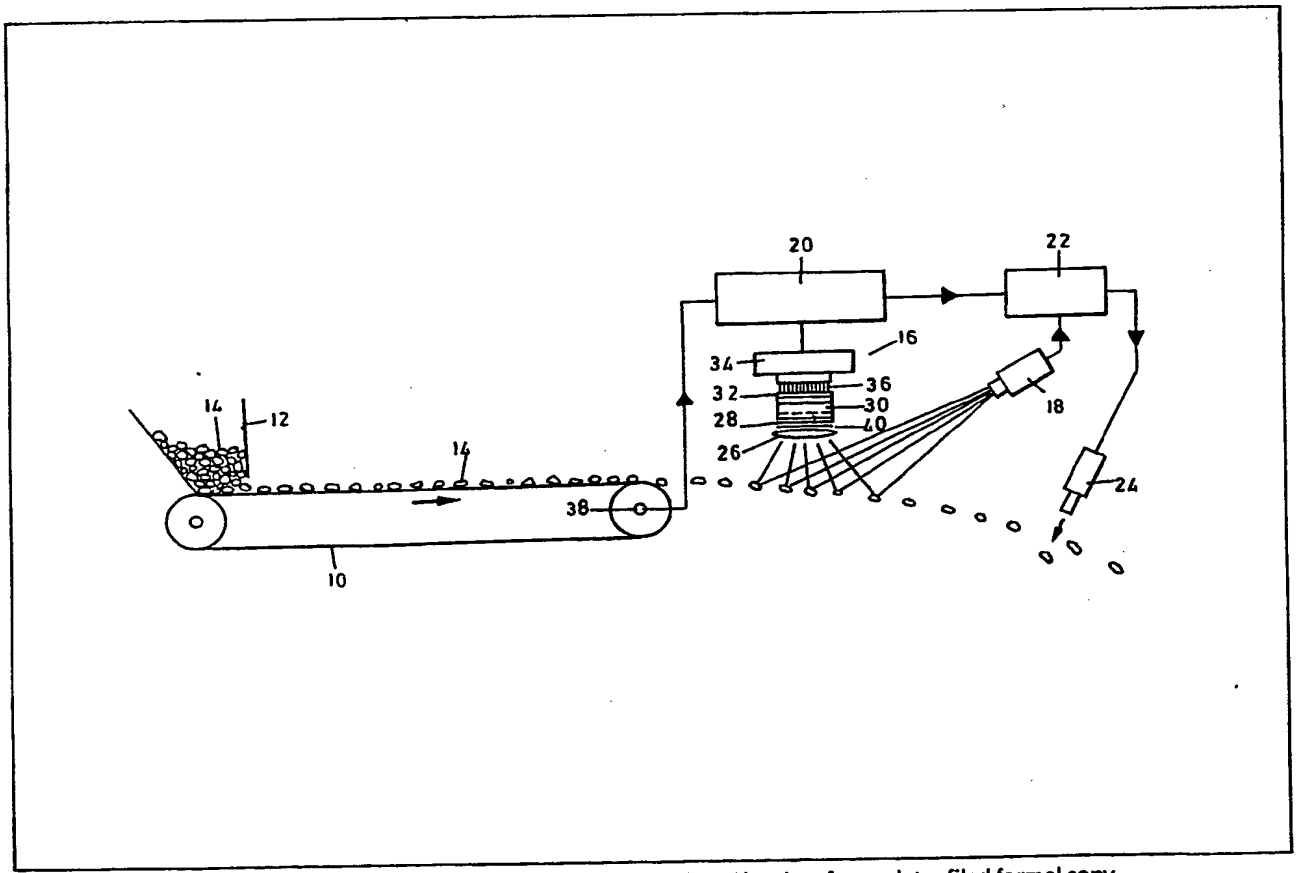
(54) **Detector for use in sorting system**

(57) A detector (16) for use in a sorting system is based on an image intensifier which includes a micro channel plate (30). The objects (14) to be sorted are irradiated by a suitable source (18) of radiation which excites secondary radiation in the objects. Alternatively the objects, depending on their nature, reflect a portion of the incident radiation in a manner which is indicative of the characteristics possessed by the objects. The radiation emanating from the objects is intensified by the micro channel plate (30) and the intensified image output by the micro channel plate is monitored, e.g. with the aid of a scanning camera (34), to detect objects with the desired characteristic. These objects are then sorted (24) from the remainder of the objects.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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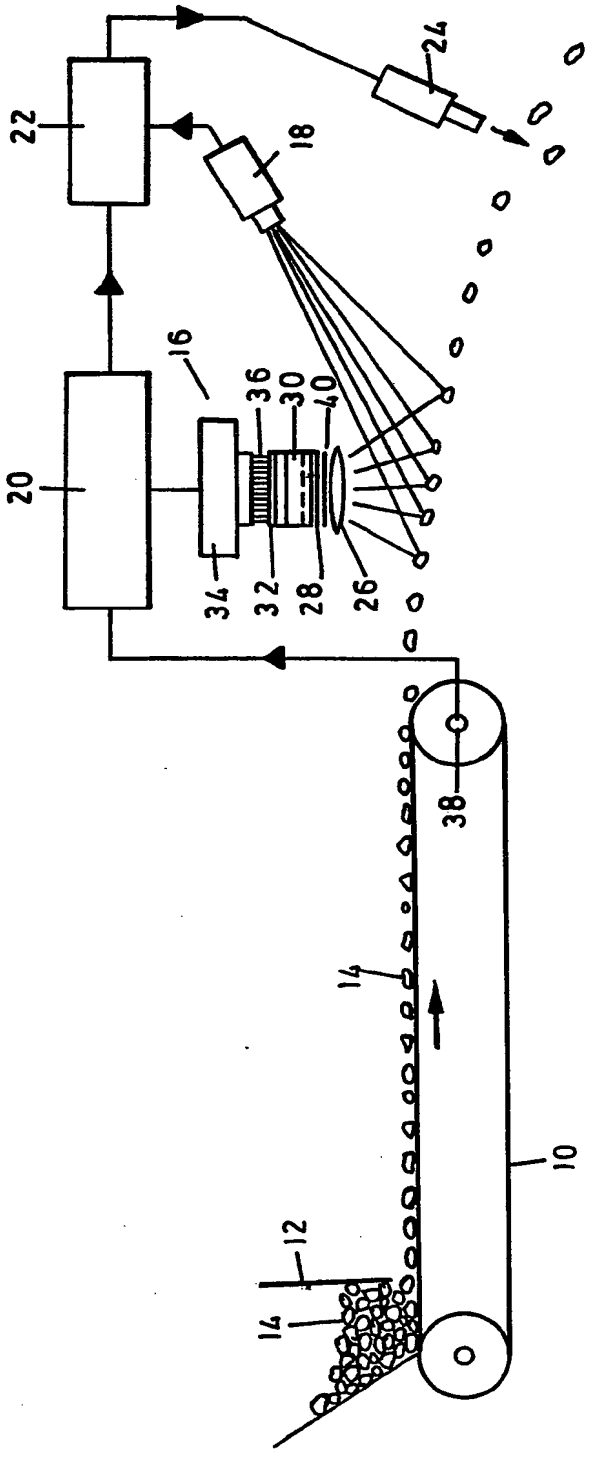

SPECIFICATION

Detector

This invention relates to a detector suitable for detecting the presence of an object with desired characteristics, or for detecting one or more desired characteristics of an object, and is well suited for incorporation in a sorting system wherein desired objects are detected amongst a plurality of objects and separated therefrom.

In many sorting applications the objects to be sorted are illuminated with radiation at a suitable frequency and radiation reflected by the objects or emitted due to the stimulating effect of the irradiating radiation is monitored to detect a desired characteristic. Due inter alia to high sorting throughputs and to the small sizes of certain objects it is essential to be able to scan the radiation emitted by a large number of objects simultaneously so that desired objects can be identified in the mass of objects. Scanning may for example be achieved by causing the illuminating or irradiating source of radiation to irradiate comparatively small group of objects, rapidly in succession, or alternatively by arranging a mechanical handling facility to separate the objects sufficiently before they are presented to the detection system.

In certain instances a device such as a solid state camera is employed. For example the specification of South African patent No. 82/2904 describes the use of an intensified line scan camera which monitors an image produced on a fluorescent screen by ore which is irradiated by X-rays. Such a device can scan and can be controlled electrically and under certain conditions offers adequate discrimination. However some devices of this type have a poor signal to noise characteristic and it is therefore necessary to irradiate the objects with a high intensity source of radiation. This may be difficult at certain frequencies. For example if the irradiating source is in the ultra violet region it is difficult to obtain the required intensity of radiation. The tubes which are available are expensive and have a short operating life and can be hazardous to personnel.

It may also be necessary, particularly in sorting applications, to make use of a polarized irradiating source so that specular reflections from the irradiated objects are avoided. The provision of a high intensity polarized irradiating source can be difficult and expensive due particularly inter alia to heat dissipation problems.

In some applications use has been made of lenses to view the material, or radiation from the material, being sorted. Arrangements of this general kind are disclosed in the specifications of U.K. patent No. 1283902, and Swiss patent No. 585588. Other patent specifications which relate generally to the present invention are those of USA patent No. 3341010, UK patents Nos. 1176747 and 2067753, German patent No. 2105914, and French patents Nos. 1575850 and 2400396.

It is an object of the present invention to provide an improved method of detecting a characteristic of an object.

The invention provides a method of detecting a characteristic of an object which includes the steps of intensifying a signal emanating from the object by means of an image intensifier, and monitoring an output signal of the image intensifier which is dependent at least on the said characteristic.

The characteristic may be any physical property of the object including its size, shape, mass, material content, surface features, or similar data, or combinations of such data.

The signal from the object may arise from the object itself or may be a signal which is stimulated by some form of excitation. For example the signal may arise from natural fluorescence of the object or from any other non-stimulated natural physical phenomenon or may be caused by irradiating the object with radiation at a desired frequency. When the object is so irradiated the signal which is image intensified may simply be radiation reflected by the object or parts of the object, i.e. be dependent on the reflectance properties of the object, or it may consist of a signal which is excited or stimulated by the irradiation process. An example of this phenomenon is the excitation of fluorescence in a diamond by means of X-ray irradiation.

The signal which is intensified may be at a known frequency or frequencies, or be within a given frequency band.

The output signal of the image intensifier may be monitored by means of a device suited to the wavelength and amplitude of the signal and depending on these characteristics use could be made of a photo diode array, an anode array, a charge coupled device, a camera, a charge injection device which may be an intensified device, or any similar or suitable device. Preferably those devices are able to scan the image. If a relatively high resolution is not required use could be made of a photo multiplier tube, or a similar low resolution device, or an assembly of such devices.

The object may be irradiated intermittently or continuously, and by one or more sources simultaneously or successively and the output signals of one or more image intensifiers may be monitored. Intermittent irradiation may be employed to reduce energy consumption or to improve the cooling of the source, or for any other reason.

The method may include the step of separating or sorting objects with predetermined output signals from objects which do not display such signals.

In accordance with the method of the invention a plurality of objects may be irradiated simultaneously. The objects may be caused to move relatively to the image intensifier or intensifiers. The objects may be caused to move in a random stream or in a plurality of rows, or with the objects in one or more rows spaced from one another.

The output signal of the image intensifier may be processed to detect or obtain a measure of physical data relating to an object. Thus the signal may be scanned to identify the position of an object relatively to a reference frame, or alternatively or additionally to detect a surface or other characteristic.

The irradiating frequency may vary according to the application and may be in the ultra violet, infra

red, optical, or X-ray frequency ranges, or in any other desired or suitable frequency range.

The method of the invention may include the step of selectively adapting the spectral response of the image intensifier to detect any predetermined frequency or frequencies in the signal which emanates from the object.

This may be done by interposing a band pass or band stop filter between the object and the image intensifier.

The method may also include the step of focussing radiation from at least the object on the image intensifier or intensifiers.

The invention also extends to apparatus for detecting a characteristic of an object which includes image intensifier means for intensifying a signal emanating from the object, and means for monitoring an output signal of the image intensifier means which is dependent at least on the said characteristic.

The apparatus may include means for focussing the signal emanating from the object or a plurality of objects on to the image intensifier means.

The apparatus may include means for selectively adapting the spectral response of the image intensifier means to a predetermined frequency or frequencies or frequency range. This may be achieved through the use of one or more filters.

The monitoring means may include a visual display such as a fluorescent screen or similar device and additionally or alternatively any other suitable monitoring aid. Preferably the monitoring aid can be scanned. Suitable devices for use in this regard are photo diode arays, anode arrays, charge coupled devices, cameras or charge injection devices.

The apparatus may include means for irradiating the object at a desired frequency. The irradiating means may comprise a source of suitable intensity at any desired frequency range for example in the ultra violet, optical or X-ray frequency ranges. The signal which emanates from the object may be a stimulated signal and lie in the same or a different frequency range, or be a reflected signal.

The irradiating source may operate continuously or intermittently.

In accordance with the invention more than one set of apparatus of the kind described may be employed, simultaneously or in succession, for detecting an object.

Each apparatus may be responsive to the same characteristic or characteristics, or to different characteristics.

The invention also extends to a sorting system which includes apparatus of the kind described and means for causing a plurality of objects to be exposed to the detection apparatus. Means for separating selected objects from the remaining objects may also be provided.

The invention is further described by way of example with reference to the accompanying drawing which schematically illustrates a sorting system which includes detection apparatus operated in accordance with the principles of the invention.

The accompanying drawing illustrates apparatus according to the invention which includes a conveyor belt 10 which is supplied from a feed chute 12 with objects 14 to be sorted, a detection device 16, a source 18 of radiation at a selected frequency, a circuit 20 for controlling the operation of the detection device 16, logic and control circuitry 22, and an array 24 of blast nozzles.

The detection device 16 includes a lens 26, a photocathode plate 28, a micro channel plate 30, and optionally, depending on the application, a fluorescent screen 32 which is coupled to a camera 34 by means of an array 36 of optical fibres.

The assembly of components 30, 32 and 36 constitutes a device generally referred to as an image intensifier. Briefly the operation of the image intensifier is as follows: photons impinging on the photocathode 28 cause electrons to be emitted from the plate and these are drawn through the micro channel plate 30 by means of a voltage bias applied to the plate. The electrons in their passage through the micro channel plate 30 initiate an amplifying effect whereby increased numbers of electrons are emitted by the plate 30 in dependence on the number of incident electrons. The electrons emerging from the plate 30 impinge on the screen 32 which emits photons, or fluoresces, thereby creating an enhanced or intensified image of the primary image. This process should be constrasted to the use of a device such as a lens which magnifies the image, or concentrates the image. A lens is a passive device, however, and it does not enhance the image, in an amplifying or active manner, as does the micro channel plate.

The frequency of the radiating source 18 is chosen in accordance with the characteristic or characteristics to be detected or identified. For example in the detection of diamonds the source 18 could be an X-ray source for it is known that diamonds fluoresce when excited by an X-ray source and at least the bulk of the accompanying gravel or gangue does not fluoresce. In photometric sorting on the other hand where a surface characteristic is being sought the source could have a frequency in the visible region so that visually contrasting colours on the objects 14 can be identified. The source 18 could also for example operate at an ultra violet frequency for this is useful in detecting scheelite which fluoresces with a blue colour.

The screen 32 is used to convert electrons emerging from the micro channel plate 30 into an optical signal. The screen is a phosphor screen and the spectral characteristics of the screen are chosen to suit the camera 34. If the camera is able to detect the electrons directly the screen 32 may be dispensed with. The use of the fibre optics 36 to couple the optical signal to the camera is also optional and will in practice be determined by the actual characteristics of the camera and the screen and the spacing between the two components.

The camera 34 is ideally a scanning device which is controlled by the circuitry 20. This enables one to detect the characteristic in question and to identify the spatial position of a detected characteristic or object or the size or mass of the object, and to keep track of a particular characteristic or object.

In use of the apparatus of the invention the objects

14 are deposited on the belt 10 which moves at a speed which is sufficiently high so as to cause the objects to be spaced from one another on the belt. At a forward end of the belt the objects are projected into free space and pass on a predetermined trajectory past the detection apparatus 16 and the nozzle array 24. The objects in space are illuminated by the source 18 and radiation reflected by the objects or excited in the objects by the incident source is focused by the lens 26 onto the photocathode place 28. The electrons emerging from the photocathode plate 28 are amplified by the micro channel plate 30 and converted into an optical signal 32 which is transferred to the camera 34 by the optical fibres 36. The camera scans the field of vision under the control of the circuitry 20 and its output signal is applied to the logic analyser 22 where it is compared to data which is determined from prior measurements on objects of known characteristics and which is stored in a suitable memory, for example of the read only type based on the desired characteristics. Alternatively, or in addition, the camera is used to detect the shape or outline of each object and thus to provide a measure of the size or mass of each object.

A comparison process of this type is naturally dependent on the nature of the objects being sorted, but it is readily accomplished with the aid of conventional techniques and lies within the ability of one skilled in the art.

The speed of the belt 10 is continuously monitored by a tachometer 38 and since the objects 14 travel on a predetermined trajectory with their positions being monitored by the detection device 16 it is possible to predict when the objects pass the array 24. Thus when a selected object passes the array 24 an appropriate nozzle is actuated in accordance with conventional techniques by means of an initiating signal from the analyser 22 and the object is deflected from its normal trajectory to a collecting bin or belt.

As an alternative to illuminating the objects in free space they could be irradiated while still on the belt. Desired objects could similarly be detected while still on the belt. Depending upon the speed of the belt the sorting step could take place as the objects leave the belt with the aid of a gate or flap or similar device.

A significant advantage of the invention lies in the fact that the source 18 may be low powered for the lack of intensity in the incident radiation is compensated for by the use of the image intensifier. Power consumption is therefore lower. This is a significant feature when the source 18 is at X-ray frequencies for the cooling of a high intensity X-ray tube can present difficulties in the field. The low power requirements may be further decreased, where applicable, by pulsing the similar benefits are obtained when the source 18 is a polarised light source.

The image intensifier could be made frequency selective through a design approach which makes the micro channel plate frequency dependent. Alternatively a band stop, or band pass, filter, as desired, for example an optical filter 40, may be inserted at a suitable location e.g. interposed between the lens 26 and photocathode plate 28, or be placed in front of the lens 26.

If, for example, scheelite is irradiated with ultra violet radiation then a filter is used to prevent reflected ultra violet radiation from reaching the scanning camera. The filter is chosen to allow the fluorescent radiation to reach the camera. The size of the object may be measured by the camera, simultaneously during the detection of the fluorescence, by irradiating the object with a second source of radiation, at an intensity well below the expected fluorescence level, and which is at the pass frequency of the filter i.e. at the fluorescence frequency. Radiation from the second source which is reflected by the object is detected by the camera and a size assessment of the object is made, and fluorescence emitted by the object is simultaneously detected.

A similar result could be achieved by the use of two sets of the apparatus described, arranged in series or any other suitable way. Contrasting surface features or other different characteristics can be detected by irradiating the object at two or more frequencies, appropriately chosen to excite the object or to bring out the contrast. Two or more image intensifiers with appropriate filters are then used to detect the different features. The source 18 could for example be a multi-frequency source.

Applications of the principles of the invention in these and similar manners are all intended to fall within the scope of the invention.

CLAIMS

1. A method of detecting a characteristic of an object which includes the steps of intensifying a signal emanating from the object by means of at least one image intensifier, and monitoring an output signal of the image intensifier which is dependent at least on the said characteristic.

2. A method according to claim 1 which includes the step of irradiating the object with radiation at least at one desired frequency which causes the said signal to emanate from the object.

3. A method according to claim 2 which includes the step of irradiating the object at least at two frequencies each of which is associated with a different characteristic of the object.

4. A method according to claim 2 or 3 in which the said emanating signal includes radiation which is stimulated by the said irradiated radiation.

5. A method according to claim 4 in which the object is irradiated at a first frequency which stimulates radiation and at a second frequency which is substantially the same as the frequency of the stimulated radiation.

6. A method according to any one of claims 1 to 5 which includes the step of locating a frequency dependent device between the object and the image intensifier.

7. A method according to any one of claims 1 to 6 which includes the step of using the said output signal to derive a measure of the mass of the object.

8. A method of sorting objects wherein a plurality of the objects are caused to move relatively to an image intensifier, at least one desired characteristic is detected in some of the objects by means of the

method of any one of claims 1 to 7, and objects with the desired characteristic are separated from the remainder of the objects.

9. A method according to claim 8 for sorting diamondiferous material wherein the material is irradiated with X-ray radiation and wherein fluorescent signals are stimulated in diamonds, contained in the material, by the radiation and are intensified by means of the image intensifier.

10. A method of sorting particulate material containing scheelite according to claim 8 wherein the material is irradiated with radiation at an ultra violet frequency and wherein fluorescent signals are stimulated in scheelite, contained in the material, by the radiation and are intensified by means of the image intensifier.

11. Apparatus for detecting a characteristic of an object which includes at least one image intensifier means for intensifying a signal emanating from the object, and means for monitoring an output signal of the image intensifier means which is dependent at least on the said characteristic.

12. Apparatus according to claim 11 which includes means for focussing the signal emanating at least from the object on to the image intensifier means.

13. Apparatus according to claim 11 or 12 in which the monitoring means includes a device for scanning the output signal of the image intensifier means.

14. Apparatus according to claim 11 which includes a fluorescent screen which produces an image which is dependent on the said signal emanating from the object.

15. Apparatus according to any one of claims 11 to 14 which includes filter means between the object and the image intensifier means.

16. Apparatus according to any one of claims 11 to 15 in which the image intensifier means includes a photocathode plate which is responsive to the said signal emanating from the object, and a micro channel plate which is responsive to the output signal of the photocathode plate.

17. Apparatus according to any one of claims 11 to 16 in which the monitoring means includes memory means for data based on the said characteristic and logic means for comparing the output signal to the data.

18. Apparatus according to any one of claims 11 to 17 which includes means for irradiating the object with radiation at least at one predetermined frequency.

19. Apparatus according to claim 18 in which the irradiating means irradiates the object at least at two frequencies each of which is associated with a different characteristic of the object.

20. Apparatus according to claim 19 in which one frequency is a frequency at which radiation is stimulated in the object, and a second frequency is substantially the same as the frequency of the said stimulated radiation.

21. A sorting system which includes apparatus according to any one of claims 18 to 20, means for causing a plurality of objects to be sorted to move past at least the said irradiating means, and means for separating objects with the said characteristic from the remainder of the objects.

22. A system according to claim 21 in which the means for causing movement of the objects includes means for projecting the objects in free space past at least the irradiating means.

23. A method of detecting a characteristic of an object substantially as hereinbefore described with reference to the accompanying drawing.

24. Apparatus for detecting a characteristic of an object substantially as hereinbefore described with reference to the accompanying drawing.

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